blood picture. The function of the nervous and cardiovascular systems might be influenced at about one or two hundred uW/cm^2. Considering that the lower power density group (<200 uW/cm^2) in our investigation mentioned above had more alteration in blood pressure and ECG, we selected 238 persons who had been exposed to microwave power density less that 50 uW/cm^2 and their age- and sex-matched individuals as control. There were still significant differences in the incidence of neurasthenia symptoms. However, there was no difference in objective indexes between the two groups in statistics. Although some reports stated that the microwave exposure group at a few hundredths of a mW/cm^2 had similar functional changes in the nervous and cardiovascular systems, it seems that there is no correlation between the exposure intensity and the changes. Gordon and other authors indicated that in low level exposure groups similar effects were observed, but symptoms were less evident and easily reversed. This impression is strengthened by the fact that after reducing the exposure levels, no further cases with pronounced dysfunction syndrome were noted.

In order to search for the threshold level of microwave bioeffects on animals, acute and chronic experiments were conducted.

Acute effects of microwave radiation on blood pressure, respiration, rectal temperature, subcutaneous temperature and ECG were observed [15]. In this experiment using rabbits, the whole body was radiated on its abdominal side with 2450 MHz continual microwave for 1 hr. There were five groups with 68 rabbits in all divided into 80 mW/cm^2, 40 mW/cm^2, 20 mW/cm^2, 10 mW/cm^2 and control. The microwave radiation induced a drop in blood pressure, acceleration of respiration, and elevation of subcutaneous and rectal temperature (Table 9).

Table 9 Variation on acute experiment

Investigated items	80 mW/cm^2	40 mW/cm^2	20 mW/cm^2	10 mW/cm^2	Control
Blood pressure drop mean (mm Hg)	25	18	22	-	-
Respiratory rate increase mean (per min.)	109	55	-	-	-
Subcutaneous tem. pure rise mean (^{0}C)	5	3.1	1.6	-	-
Rectal tem. pure rise mean (^{0}C)	2	1.3	0.3	-	-

- no significant changes

The chronic experiment was conducted with 16 rabbits and 40 rats. The rabbits were divided into four groups at random from which three groups were irradiated with three levels (10, 1, and 0.1 mW/cm^2) and one served as control. The rats were divided into four groups, from which three groups were irradiated with the other three levels (5 mW/cm^2, 0.2 mW/cm^2 and 0.01 mW/cm^2) and one was control. The exposed groups were irradiated six hours daily for four and a half months. A certain power density of microwave (300 mW/cm^2) induced EEG frequency slowing and amplitude increasing. The most pronounced changes of ECG were bradycardia, tachycardia and R wave widening. Leukocyte and leukocytic alkali phosphatase increased in the first half a month and then there were no changes. Blood presure fluctuated. Mistakes at Y-labyrinth test appeared to tend to increase. The relationship between these variations and power densities is shown in Table 10.

Table 10 Relation between the variance of observed indexes and power densities

Items	10 mW/cm^2	5 mW/cm^2	1 mW/cm^2	0.2 mW/cm^2	0.1 mW/cm^2	0.01 mW/cm^2	control
EEG							
amplitude	++	/	-	/	-	/	-
frequency	++	/	++	/	-	/	-
ECG							
heart rate	/	++	/	-	/	-	-
R widen	/	++	/	++	/	-	-
Leukocyte	/	++	/	-	/	-	-
L A P	/	+	/	-	/	-	-
Blood pressure waved	++	/	-	/	/	-	-
Rectal tem.	-	-	-	-	-	-	-
Body weight	/	+	/	-	/	-	-

++ represents the variance with significant difference
+ represents the variance only with a tendency change
/ represents no animal exposed at this power density level
- shows no significant changes

The experimental data are preliminary and limited. A large number of experiments have been carried out in other countries.

The threshold of biological effects, which differs from health hazards, is extremely low. The average heart rate decreased during the pulsed microwave energy affected on frog hearts under certain conditions at only 0.003 mW/cm^2 average power density presented (Frey). The threshold of auditory responses for cats, the threshold of avoidance by rats of pulse modulated microwave, and the threshold of incidence efflux of calcium ions from the isolated chick or rat cerebral tissue (with frequency "window" modulated in amplitude) are far below or near 0.1 mW/cm^2. The threshold of hazardous effects in acute experiment is rather high and usually depends, to a great extent, on overheating.

The most important experiments, on which to base a set of safety standards, are long-term low level exposures. Dumenskij [16] reported an investigation performed at 10, 2.4, 1.9, 0.06, 0.01, and 0.006 uW/cm^2 for wavelength 6 m and 20, 10, 5 and 1 uW/cm^2 for 12 cm wavelength. The animals (rats and rabbits) were irradiated 8-12 hr. daily for 120 days. The experiment showed that in the conditioned reflex activity, the latent period was longer, reflex reactions to positive stimuli weakened, and the number of these missing increased. In this investigation these changes in the central nervous system were supplemented and confirmed by EEG, and biochemical studies including cholinesterase activity and sulphydryl (SH) groups in the blood. Changes in blood composition and morphologic structure of the tissues and organs of the animals were also observed. The author pointed out that prolonged action of electromagnetic energy of low intensities in the UHF and SHF ranges resulted in appreciable changes. The biologically active intensities of electromagnetic fields were 10-0.06 and 20-5 uW/cm^2 for UHF and SHF ranges respectively. Such low thresholds of hazardous effects of RF or MW radiation have not been supported by other reports. In some studies observed on the same systems and functions, negative results were obtained with even much higher power densities. However, a number of chronic experiments on bioeffects of RF and MW showing lower thresholds have been made by other Soviet authors.

In the United States, D'Andrea [17] reported a chronic experiment of exposure to 2450 MHz microwave. Long-Evans male rats were exposed 8 hr. a day for 16 weeks to microwaves at an average power density of 5 mW/cm^2. The dose rate was 1.23 mW/g. After exposure, it revealed a significant depression of behavioral activity. There were no effects on body mass, mass of adrenals, and levels of 17-ketosteroids in urine. Another long term experiment recently was presented by Guy and McRee [18,19]. Four rabbits were exposed to 2450 MHz microwave for 6 months. Daily duration of exposure was 23 hr. and continued across 180 consecutive days. The power density at the body axis of the animals was 7 mW/cm^2 and at the head location was 10 mW/cm^2. The average whole body SAR was 1.5 W/Kg. Eosinophil percentage, albumin and calcium levels were

significantly lower in exposed than in control rabbits. Thirty days after termination of exposure, no change in hematological parameters was observed, but a significant decrease in albumin/total globulin ratio was measured in the exposed animals. Lymphocytes from exposure animals showed a significant suppression in responsiveness to pokeweed mitogen. That microwave radiation may suppress immunological competence was reported by other studies. It seems that the power density of several mW/cm^2 may be critical to the effects observed on the immune system.

If we review the animal and human data on biological effects of MW and RF radiation, we find that there are considerable differences and controversy in this field. That the safety standard must be able to protect the health of the workers without obstructing the microwave techniques in extensive application. In accordance with our investigation and experiments, and referring to the experience of other countries, the power density at average 50 uW/cm^2 in the working place for a duration of six hours daily has been proposed as the tentative microwave occupational exposure standard in our country.[2] If it is eight hours exposure a day, it must be less than 40 uW/cm^2. 300 uW/cm^2 is the limited dose for a whole working day. However, it is not permissible to be over 5 mW/cm^2. This tentative exposure standard has been adopted in local areas in our country for two years. It will be further perfected and decided by the end of this year.

2. Radiation frequency.

Because of the different reflection, propagation and absorption for different frequencies of electromagnetic field, the specific absorption rate must be different in a biological target from the same incident power density. Additionally, some special effects may occur at a certain frequency range. It is necessary to set separate standards for some frequency ranges.

Ermolajev and Subbota [20] suggested a formula to express the relation between the frequencies and electric field strengths, in which the equivalent bioeffects could be observed.

$$E_1 = E_2 \cdot \sqrt{\frac{f_2}{f_1}}$$

E_1 electric field strength in V/m for f_1 (MHz)
E_2 electric field strength in V/m for f_2 (MHz)

The formula was derived from the following data (Table 11).

Table 11 Relation between frequencies and electric field strengths (V/m)

Bioeffects	Species	3 MHz	14 MHz	22 MHz	69.7 MHz	150 MHz	300 MHz
Functional alteration	rabbit	500 (615)	250 (285)	200 (220)	150 (125)	100-150 (90)	60 (60)
Death	mice	10000		3000			1000
	rat		5000		2000		

The properties of electromagnetic energy absorption and distribution under various frequency ranges were studied and manifested by many scientists (Schwan, Guy, Gandhi et al). In humans, maximum whole body SAR occurs in the frequency range of 60-100 MHz, with a peak at approximately 70 MHz. Human absorption at frequencies below 30 MHz and above 500 MHz is much less than that at the resonant frequency. Partial body resonant absorption occurs at 150 MHz for the arm and at 350 MHz for the head. In general, small animals absorb MW energy maximally at frequencies near or above 500 MHz. In view of this, the formula mentioned above is not fit for humans. It seems that the minimum intensity of maximum permissible exposure level should be at the frequency range of 30-300 MHz which is adopted in Canada's new standard. A new proposed exposure standard in America which is based on the whole body SAR equal to 0.4 W/kg is also the strictest at the resonant frequency range.

The lower limit of frequency regulated in the exposure standard is 10 MHz in some countries. The frequency range of electromagnetic field now widely used in industry of our country is from 0.25 MHz to 40 MHz and microwave. It seems that the frequency lowest limit of exposure standard should be at least at 0.2 MHz in RF range. Some cases of workers who suffered from typical neurasthenia resulting from RF radiation were found by the present author. A worker was exposed to 250 KHz near zone field at the electromagnetic field strength of about 400 V/m and 20 A/m over 5 years. Systolic blood pressure of this patient was highly unsteady with a 60 mm Hg fluctuation or so within a day. Bradycardia (ECG), slight leukopenia, emission and sterility occurred. Decrease in activity of sperms was found by laboratory examination. Slight abnormality in EEG appeared with more θ waves. After transient withdrawal from work with RF sources, the neurasthenia symptoms were observably relieved. After cessation of exposure to RF radiation over one year, the neurasthenia symptoms disappeared and disfunction of the cardiovascular system tended to recover. Similar, less extensive symptoms also occurred in a few other persons working at the same radiation condition. Another case is a woman who lived near a radio broadcast antenna with working frequency at 800 KHz. Keratoconjunctivitis resulting from lack of tear occurred while the patient was living there, and alleviated after she left there for

several weeks. This phenomenon happened several times. The electric field strength in her bedroom was about 20 V/m. Perhaps the patient was extremely sensitive to such an RF electromagnetic field. Perhaps disfunction of the endocrine system resulting from RF radiation was the main cause in reducing secretion of tears. Epidemiological data on RF radiation in China and some other countries also demonstrated that sufficiently intense RF radiation including the frequencies from 0.1 MHz to 10 MHz also can produce harmful effects. Several decades V/m will be adopted as the maximum permissible electric field strength for RF range in China.

3. Other radiation conditions

Several factors other than intensity, dose, and frequency range may also influence the harmful effects of RF and MW radiation. Pulsed and continual microwave may be different for their bioeffects. In Czechoslovakia, the exposure standards for them are different. In the new exposure standard of Canada, the maximum permissible level was differentiated between whole-body exposure and exposure of extremities. A distinction between continuous (stationary field) and intermittent (nonstationary field) exposure was made in Poland and then accepted by the Soviet Union in their microwave safety exposure standards. The ambient temperature and the presence of X-ray radiation are also considered in the USSR occupational exposure standard. All those factors should be investigated and studied further.

Finally it should be pointed out that the safety exposure standard will continue to be perfected with increasing knowledge.

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